

## *Prehistoric Archaeology and Evidence of Coastal Subsidence on the Coast of Maine*

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### ABSTRACT

Analysis of archaeological site locations can be used to help assess localized rates of sea-level rise provided certain conditions are met, and assumptions about the relationship between sea level and archaeological land surfaces are accurate. Provided it can be shown that marine-adapted peoples lived on contemporary shorelines, and that a particular stretch of shoreline exhibited equal potential for habitation, then differential preservation by age of site may be indicative of differential land erosion rates. This model is used to discuss the relative rates of sea-level rise for the Maine coast, divided into four shore zones.

For each of the zones the archaeological evidence is reviewed together with an assessment of site loss due to sea-level rise and coastal erosion. It is concluded that the oldest coastal sites are found in the Penobscot Bay area, where 5000 year old sites are still relatively intact. The shortest record occurs in Passamaquoddy Bay where sites are no older than 2500 years. Erosion of sites, and perhaps rate of submergence, is clearly greater in Passamaquoddy Bay than elsewhere in the study area.

In addition to documentation of differential site preservation, archaeology can contribute to sea-level rise studies through the analysis of changing habitats resulting from drowned estuaries. Research on the oyster shell middens along the Damariscotta River indicates just over 1 meter of sea-level rise over the past 2500 years.

These figures may be compared with data gathered by other methods to arrive at a synthetic statement of sea-level rise and/or coastal submergence due to crustal subsidence.

### INTRODUCTION

Archaeological sites have long been used as a means for relative dating of landforms and surfaces. Archaeological dating has been invaluable for reconstructing river terrace, coastal, and delta formation sequences in the lower Mississippi River valley (McIntyre, 1958, 1971; Saucier, 1974). Archaeology has also been used to document tectonic and sea-level fluctuations around the Mediterranean Sea (Flemming, 1969, 1978; Galili and others, 1988; Ronnen, 1983), on the French Atlantic coast (Scarre, 1984), along the Peruvian Coast (Richardson, 1983; Sandweiss and others, 1983; Sandweiss, 1986), on the Brazilian coast (Fairbridge, 1976), and in the Arctic (Andrews and others,

1971). There have also been many attempts to use archaeological dating to provide sea-level data along the U.S. east coast (e.g., Brooks and others, 1979; Brooks and others, 1986; Colquhoun and Brooks, 1986; DePratter and Howard, 1981; Goldthwait, 1935; Holmes and Trickey, 1974; Johnson, 1942; Johnson and Raup, 1947; Michie, 1973). In this paper we use prehistoric sites, ranging in age from 6,000 to 350 years before present (B.P.), to independently assess relative sea-level rise and coastal subsidence along the Maine coast. The basic assumption underlying this practice is that cultural occupation of a surface postdates the geologic processes that created the surface. Dating the cultural

occupation, therefore, provides a minimum age for the surface, or landform.

These applications involve many assumptions and expectations about geological processes (Belknap and Hine, 1983), cultural behavior, archaeological site formation (Gluckman, 1982), site preservation, and archaeological research. The logical foundations of the archaeological dating of landforms have never been completely outlined. Because we are attempting to independently corroborate geological studies of sea-level change along the Maine coast, we feel that it is necessary to make explicit the assumptions behind our study. Moreover, such an exercise helps to insure against the possibility of circular reasoning (Kellogg, 1988).

## ASSUMPTIONS

The idea that archaeology might contribute useful information to a study of coastal stability is based on a simple premise:

Older coastal archaeological sites indicate an older, more stable, coastline.

Underlying that premise is a series of assumptions about cultural behavior and archaeology, geomorphology and coastal processes, and the interaction between culture and environment. If conclusions about coastal stability or relative sea-level rise are to be drawn from coastal archaeology, then the validity of those assumptions must be determined. Table 1 outlines these assumptions for the Maine coast. The discussion that follows is keyed to Table 1.

### *Geologic Assumptions*

**I. The geology of the Maine coast is uniform.** Direct comparison among archaeological sites all along the Maine coast would assume that the geology of the entire region can be compared, and that relative sea-level fluctuations have affected all areas in the same ways. Coastal processes, then, would have similar consequences for all archaeological sites along the coast.

This assumption does not apply to the Maine coast. The coast can be divided into four, or five, sections of similar geological structure (Kelley, 1987; Timson, 1977; Shipp and others, 1985:6-9). Southwest of Cape Elizabeth, the coast is dominated by wide arcuate bays with sand beaches and marsh systems extending between bedrock promontories. From the Portland area to Owls Head on the west side of Penobscot Bay, the coast is composed of complex, indented embayments, controlled by deformed metasedimentary bedrock (see, for example, map by Hussey in this volume). The section from Penobscot Bay east to Cutler is dominated by granitic, intrusive rocks. The western half of this section is composed of large islands and bays, and the eastern half has smaller islands and bay complexes. The rest of the coast to the east is characterized by linear cliffs of metavolcanic bedrock.

TABLE 1. MAJOR ASSUMPTIONS IN THE USE OF ARCHAEOLOGY TO STUDY COASTAL STABILITY

Premise: Older coastal sites indicate older coastline; therefore, slower relative sea-level rise.

**I. The geology of the Maine coast is uniform.**

- A. Similar geological processes operate all along the coast.
- B. Coastal processes have not changed through time.
- C. Geological research has been uniform along the coast.

**II. The archaeology of the Maine coast is uniform.**

- A. Cultural occupation has been spatially uniform.
  - 1. Initial occupation of the coast occurred about the same time.
  - 2. Similar settlement locations were available in all areas.
  - 3. Archaeological sites are primary refuse discarded at the location of use.
  - 4. Sites were along the shore when occupied.
- B. Cultural occupation was uniform through time.
  - 1. All areas of the coast were equally attractive to settlement through time.
  - 2. Similar settlement locations were available through time.
- C. Archaeological research has been uniform

The bedrock differences create a wide variety of coastal environments and situations. Exposure to coastal processes produced by waves and currents is extremely diverse (Kelley, 1987). Tidal range grades from 2.4 m at Kittery to over 6.5 m at Eastport. Furthermore, surficial deposits are not uniform along the coast (Thompson and Borns, 1985). Tills cover most of the landscape, but can be interbedded with and overlain by glacial outwash or Presumpscot Formation glaciomarine silts and clays. Thicknesses of unconsolidated sediments are also highly variable.

**I. A. Uniform response processes.** Although the physical laws that govern waves and currents can be held constant, the geologic and geomorphic variability of the coast means that processes and responses are diverse. For example, sand beaches (Nelson, 1979; Nelson and Fink, 1980; Fink and others, 1988) respond to coastal processes differently than do rocky cliffs (Emery and Kuhn, 1980, 1982). Relative sea-level fluctuations, therefore, may result in different geomorphic responses (see Fink, 1985; Kelley, 1985; Kelley and others, 1986; Sanger and Kellogg, 1985a). Barrier beach type shores, as in the southwest section of the Maine coast, respond to sea-level rise by migrating landward. Unconsolidated sediments comprising the terrestrial shore are often overridden by sand. Former terrestrial sediments may be exposed to erosion at wave base as continued submergence moves the beach farther landward (Belknap and Kraft, 1981, 1985; Fink, 1985; Kraft and others, 1983; Schwartz, 1967).

Where barrier beaches do not occur on the Maine coast (i.e., most of the coast east of Cape Elizabeth), sea-level rise largely results in the direct erosion of unconsolidated sediments. The course of erosion, however, proceeds in different fashions depending on the composition and configuration of the shore, and exposure to marine and climatic processes (Kellogg,

1982:111-117, 1984:100-133, 1985a; Timson, 1977). Thus, uniform responses to geological and marine processes do not occur along to the entire Maine coast.

**I.B. Uniform coastal processes through time.** A complicating factor of coastal processes is brought out by models of the Gulf of Maine tidal system (Grant, 1970; Scott and Greenberg, 1983). Tidal range has changed as sea level has risen throughout the Holocene. The present day phenomena of the coast may not be directly representative of past processes at a particular location. Moreover, postglacial, relative sea-level rise against a complex topography can create changing shoreline configurations, and bathymetry. Thus, wave refraction patterns would change through time, even if wave approach patterns from storms remained constant.

**I.C. Uniform geological research.** Finally, geologic research has been uneven along the coast of Maine. Only very recently has intensive research been carried out all along the coast (Belknap and others, 1987; Hay, 1988; Kelley and others, 1987a; Kelley and others, 1987b; Kelley and others, 1988; Shipp and others, 1985; Shipp, 1989). Specific information on the impacts of sea-level fluctuations on shore processes are still lacking for many areas, but are the topics of active research by the Maine Geological Survey and the University of Maine.

In summary, it would be erroneous to base a study of coastal stability, relative dated by archaeological sites, on assumptions of uniform geology along the coast of Maine. Geological variability significantly complicates archaeological comparisons among different sections of the coast.

### Archaeological Assumptions

**II. A. 1. Uniform initial occupation of the coast.** It must be assumed that the entire area of interest was settled at the same early date. Early coastal occupations (see Figure 1 and Table 2) have been discovered in Newfoundland and Labrador where emergence of postglacial shores has occurred (Andrews and others, 1971; McGhee and Tuck, 1975; Tuck, 1976a, b; Tuck and McGhee, 1975). Traces of similar occupations have been claimed for northern New England (Tuck, 1975), and may be expressed at the Turner Farm and Goddard sites in Maine (Bourque, 1975; Bourque and Cox, 1981), although the earliest intact Maine coastal sites date no older than about 5200 B.P. (Bourque, 1975). The earliest dated coastal occupations in southern New England are around 5000 B.P. at the Boylston Fishweir site at Boston (Arnold and Libby, 1951; Byers, 1959; Dincauze, 1973, 1988; Johnson, 1942; Kaye and Barghoorn, 1964), and the Hornblower II site on Martha's Vineyard (Ritchie, 1969; Richardson, unpublished). Farther south, oyster shell middens along the lower Hudson River estuary have been dated to about 7000 B.P. (Brennan, 1974).

Although the dates for initial occupation of coastal zones in general has been the subject of much discussion (Bailey, 1983; Bailey and Parkington, 1988; Braun, 1974; Osborn, 1977; Ol-

dale, 1985; Perlman, 1980; Snow, 1972), an assumption of early Holocene coastal occupation seems reasonable. Habitation of the Maine coast, however, may be complicated by changes in the environments of the Gulf of Maine (Sanger, 1975). Conditions in the Gulf of Maine may not have been conducive to intensive occupation much before about 6000 B.P. There were, however, people both to the north and south of the Maine coast utilizing coastal resources long before the earliest dated occupations of sites along the Maine coast. Beach finds and material dredged up by fisherman (Sanger, 1975; Spiess and others, 1983; Sanger, 1988) also suggest earlier occupation along the coast than is preserved on land.

**II. A. 2. Similar settlement locations available.** Because there is great geologic variation in the coast, the assumption that similar types of settlement locations were available is unwarranted. Settlement pattern analysis of Ceramic Period shell midden sites in the Boothbay (Kellogg, 1982) and Muscongus/St. George (Kellogg, 1984) regions found many similarities in settlement patterns, but minor differences due to environmental variation occur. Since these two regions are adjacent in the

TABLE 2. KEY TO <sup>14</sup>C DATED SITES SHOWN ON FIGURE 1.

Archaeological Site	Lab Number	Material Dated	Reference
A. Sandy Cove	SI-1791	Ch	Fitzhugh, 1975
B. Arrowhead Mine	SI-1799	Ch	McGhee and Tuck, 1975
C. Forteau Bay 3	P-687	Ch	Wilmeth, 1978
D. Port aux Choix	I-3788	Ch	Tuck, 1976b
E. Curtis	GSC-834	Ch	Wilmeth, 1978
F. The Beaches	SI-1384	Ch	Carignan, 1975
G. DeEe-3a	Qu-444	Ch	Barrette and others, 1981
H. Savoie	S-713	Ch	Rutherford and oth., 1975
I. Bear River	S-158	Ch	Wilmeth, 1978
J. Port Mouton	GaK-1271	Ch	Wilmeth, 1978
K. Minister's Is.	Y-1293	Ch	Wilmeth, 1978
L. Gt. Spruce Is.	SI-6367	S-My	Sanger, unpublished
M. Goddard	SI-4255	Ch	Bourque and Cox, 1981
N. Fernald Point	SI-3428	Ch	Sanger, 1980
O. Nevin	SI-1551-C	Sw	Byers, 1979
P. Kidder Point	Beta-5486	Ch	Speiss and Heddon, 1983
Q. Turner Farm	SI-1925	Ch	Bourque, 1975
R. 16-154	SI-6933	S-M	Kellogg, 1985b
S. Stanley	SI-1532	Sw	Sanger, 1975
T. Glidden Midden	SI-6361	S-O	Sanger and Sanger, 1986
U. Davis Tobie	RL-748	Ch	Bourque, unpublished
V. Moshier Is.	Dic-2428	S-O	Yesner, 1984b
W. Seabrook Marsh	GX-4824-G	HB	Robinson, 1985a
X. Peddock's Is.	GX-2528	UR	Dincauze, 1974
Y. Boylston Street	O-1902	W	Dincauze, 1973
Z. 19BN308	GX-9703	S	Borstel, 1984
AA. Hornblower II	SI-7125	S-M	Richardson, unpublished
BB. Jamestown Brg.	Beta-9256	UR	Cox, 1985
CC. Staten Is.	I-5331	Ch	Ritchie and Funk, 1973
DD. Fralinger	I-6730	Ch	Mounier, 1974
EE. Dogan Point	L-1381	S-O	Brennan, 1976

Key to Material codes: Ch= Charcoal; S-My= *Mya arenaria* shell; Sw= Swordfish bone; S-M= *Mercenaria mercenaria* shell; S-O= *Crassostrea virginica* shell; HB= Human bone; W= Wood; UR= unreported; S= unspecified or mixed shell.

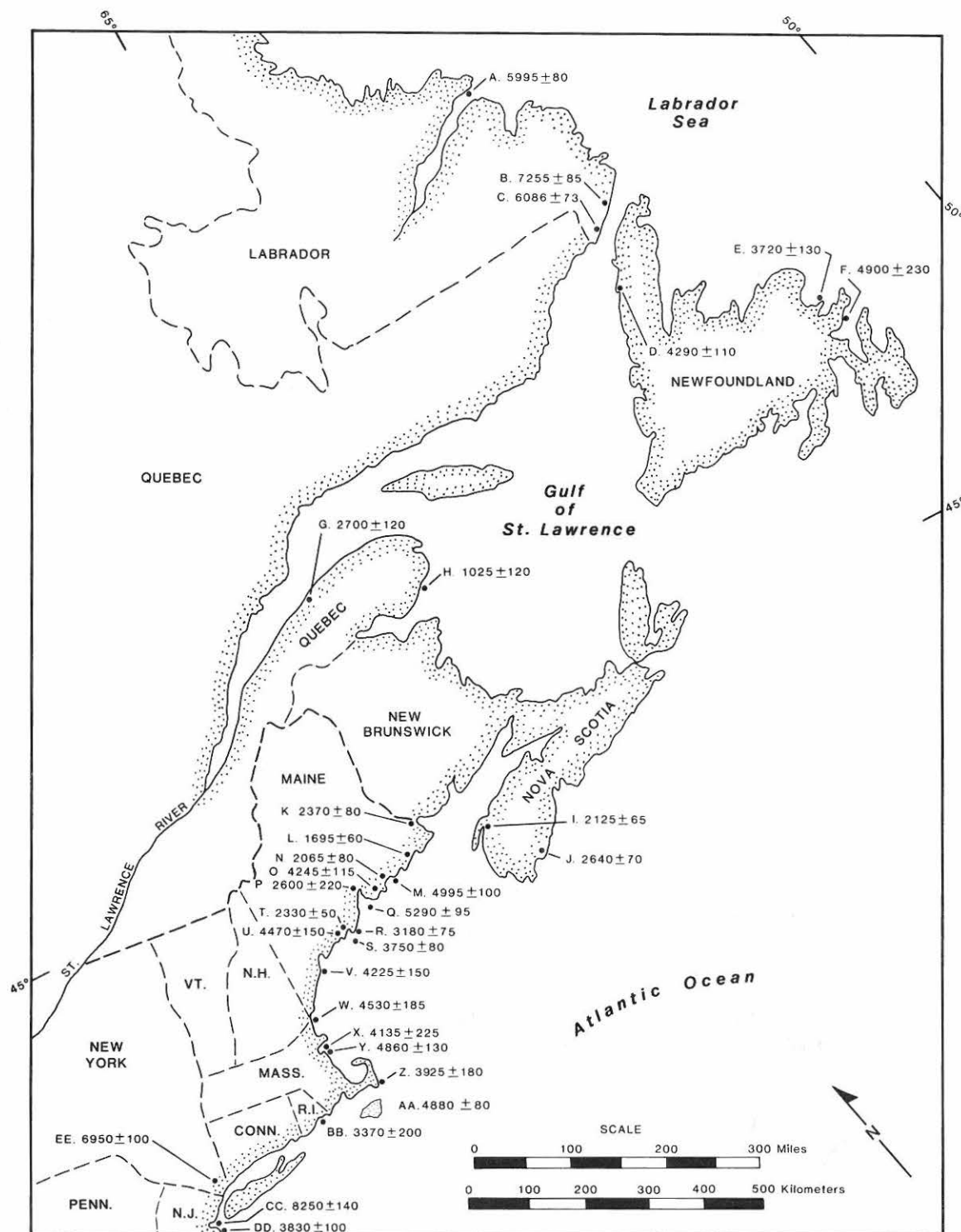


Figure 1. Early radiocarbon-dated coastal archaeological sites. Sites shown are coastal habitations that reflect a definite association with contemporaneous sea level. A few sites are less clearly associated with sea level, but reflect a prehistoric presence in the coastal zone. Not all radiocarbon-dated sites are shown. A key to the locations shown on the figure is provided in Table 2.



west-central Maine coast, further differences might be expected among the major geological divisions of the coast. Sites in Casco Bay (Yesner, 1979), for example, are oriented differently in relation to wind approach directions than sites in the Boothbay area because of differences in bedrock orientation.

**II. A. 3. Archaeological sites are primary refuse.** The assumption that Maine coastal archaeological sites are primary refuse (in the sense of Schiffer, 1972) is valid in the majority of cases. Evidence from numerous excavations indicates that most sites were villages or campsites, and not simply trash dumps formed by transporting garbage away from occupation areas, or created by shucking shellfish away from the residential area.

**II. A. 4. Occupation was at the contemporaneous shore.** All evidence indicates that sites on the present coast were along the contemporaneous shore during occupation (see discussion of Passamaquoddy Bay for some exceptions, however). Some shell midden refuse may have been deposited over the bank into the intertidal zone, but has been dispersed by marine processes. Neither are Maine's coastal sites redepositional (Gluckman, 1982); that is, they have not been reworked by geological processes. For example, sites have not been eroded, reworked, and emerged during sea-level fluctuations.

**II. B. Uniform cultural occupation through time.** Temporal uniformity of coastal occupation has not been established for the Maine coast. In fact, gaps in occupation are found in many sites. The Turner Farm site, however, contains a record of almost continuous occupation, at least on a seasonal basis, throughout the last 5000 years. It is likely that gaps in occupation along some sections of the coast have resulted from the changes in environments that have occurred. Before a conclusion about coastal stability could be drawn from the existence of such gaps, cultural factors have to be ruled out.

**II. B. 1. All areas were equally attractive to settlement.** A major assumption is that all areas of the coast, despite variations in the physical environment, were equally attractive to prehistoric occupation throughout the past. If some areas of the coast developed useful resources earlier than other areas, or if some areas never developed attractive subsistence resources, then differential settlement could result in spatial and temporal hiatuses in archaeological data.

**II. B. 2. Similar settlement localities were available.** Again, the geologic variation in the coast and complex interactions between shores and relative sea-level rise have probably influenced the availability of suitable or desirable settlement locations. Thus, gaps in settlement may be due to the lack of campsites and not coastal erosion due to sea-level rise. Assumptions of cultural uniformity through time are not warranted on the strength of currently available data.

**II. C. Archaeological research has been uniform.** The presence of an archaeological site on the coast is the result of prehistoric cultural activity. Preservation of the site depends on the effects of natural processes that can destroy sites. Archaeological interest in the investigation of a site is the final factor influencing our knowledge of coastal prehistory.

TABLE 3. MAINE COASTAL ARCHAEOLOGICAL SITE DATA BY GEOLOGICAL COMPARTMENT.

Geologic Region	No. of Sites	% of Sites	Coastal Length (km)	Surveyed Length (km)	Percent Surveyed
Southwest	27	1.7	504	<25	>5%
South-central	816	51.5	1637	>1000	>60
North-central	680	43.0	2436	>500	>20
Northeast	60	3.8	681	?	?
Totals	1583	100.0	5285	>1515	>29

Coastline lengths for each geological region were taken from Kelley (1987) and measured from 7.5' quadrangles. Actual figures for the length of coastline surveyed for archaeological sites are not available for some sections of the coast (Speiss, personal communication). Estimates of shore surveyed are based on measurements by Kellogg (1984:55), and review of unpublished survey reports and notes on file at the University of Maine Archaeology Lab in 1986. The type of survey has varied so that the numbers provide only a rough guide to the data base.

Archaeological research has not been uniform along the coast, and the data base is of mixed utility. Only a few areas have been intensively and systematically surveyed for sites (Table 3). The areas that have received the most interest are those where sites are more obviously abundant, or large, and most accessible. Coastal erosion is a factor because sites have been exposed to discovery by erosion. Furthermore, archaeological research since the 1860's has had very different purposes, and therefore, methods and results. Information gathered by one study is not always comparable with other studies. For example, coastal stability was a major component of the research centered around Muscongus Bay, Boothbay, the Damariscotta River, and in part, Passamaquoddy Bay. Other areas of the Maine coast have less useful data relative to the issue of sea-level rise. Thus, archaeological knowledge of the coast of Maine is not even.

## CHRONOLOGY

### Radiocarbon Dating

Age determinations for archaeological sites are based on two different, yet related techniques: radiocarbon dating and comparative dating. Although radiocarbon dating needs little or no introduction as a technique, there are a number of technical and associational problems that bear on the current discussion. Many archaeological excavations yield inadequate amounts of wood charcoal for dating. Although charcoal is preferred, other organic items, such as bone, antler, or shell, are often submitted for dating.

Because most of the coastal sites are shell middens, an attempt has been made to use the ubiquitous shells for dating. Problems associated with shell dates in Scandinavia were discussed by Mangerud (1972). In other parts of the world various difficulties, which range from old  $^{14}\text{C}$  in the marine environment

(Stuiver and others, 1986) to carbonate uptake by shells from local calcareous rock (Tanaka and others, 1986) have been noted.

A comparison of radiocarbon dates on a small number of paired charcoal and shell samples from sites in the Passamaquoddy Bay region of New Brunswick (Sanger, 1981a) found that dates overlapped at the one standard deviation range. Borstel (1984) reported dates on paired charcoal and shell samples from Cape Cod sites; preliminary indications were that the shell dates may be several hundred years too old compared with charcoal dates. Bourque (personal communication) has commented that the shell dates received from the Turner Farm site in Penobscot Bay seem too young compared with charcoal dates. As part of a program to assess the utility of different shell types for chronology purposes in the Boothbay Region, soft-shell clams (*Mya arenaria*) and American oyster (*Crassostrea virginica*) from 17th century contexts at the Pemaquid Restoration site were radiocarbon dated. It was hoped that a correction factor, if necessary, could be determined for this particular research area by dating shells of a known, pre-bomb age. The preliminary results, prepared by R. Stuckenrath (personal communication), are inconclusive because no consistent trends can discerned.

Shell dates from sites in the Boothbay and Muscongus Bay regions, when compared with charcoal dates, indicate that there are problems yet to be solved with shell dates. In general, it would seem that shells from the marine environments of the central Maine coast may date too young when compared with charcoal. To what extent this is a matter of the marine environment in general, localized carbonate availability, or even post-mortem carbon uptake from shells higher up in the stratigraphic column of shell middens, is unknown. Because the experiments necessary to solve these problems have not been undertaken, a potentially valuable dating tool is under-developed.

It is important to stress that, in our opinion, shell dates should not be condemned out of hand. For example, oyster shells from the Damariscotta River shell middens returned dates that meet our expectations based upon charcoal dating, and are, therefore, utilized in this chapter. Until such time as the required level of experimentation can be carried out, our policy is to use shell dates only when charcoal is unavailable, and there is no reason to believe that there is a biasing affect.

### Comparative Dating

In addition to direct radiocarbon chronology, we utilize a chronology based indirectly on radiocarbon dating. In the comparative dating methodology, stylistically similar artifacts within an area are considered to be of roughly the same age. The theory behind this approach is basically an "index fossil" one, and has been demonstrated appropriate in this and many other areas. Cumulative research has demonstrated that along the coastal regions of Maine there are a number of highly distinctive artifacts that occur only within restricted time periods. Other artifacts may be found throughout the archaeological record and are thus of little value as temporal markers.

TABLE 4. CULTURAL CHRONOLOGY FOR THE MAINE COAST.

1000 B.P.	Late Ceramic	
2000 B.P.	Middle Ceramic	
3000 B.P.	Early Ceramic	
4000 B.P.		Susquehanna Tradition
5000 B.P.	Late Archaic	Moorehead Phase
6000 B.P.		
7000 B.P.	Middle Archaic	
8000 B.P.	Early Archaic	
9000 B.P.		
10,000 B.P.		
11,000 B.P.	Paleoindian	

Table 4 lists the cultural time periods, and their ages based on radiocarbon dates. Following regional convention, we label the time periods by a terminology inherited from the pre-radiocarbon dating era. There are strengths and weaknesses involved with the comparative dating technique. One of the strengths is that it assists in overcoming the problem of inadequate charcoal for dating purposes. In a limited survey and testing program archaeologists may recover diagnostic artifacts but not enough charcoal for dating, or the charcoal may not be in good association with the artifacts for any of a number of reasons. Dating random, unassociated bits of charcoal from any archaeological site is of limited utility. Under these circumstances, it is better to rely on a well-dated, comparable artifact assemblage from a nearby site. There is a potential problem with the comparative method in that it assumes a commonality of artifact forms within a particular research area at any given time.

Overall, the comparative dating technique, when applied with appropriate caution, is a valuable one, and for the purposes of the following discussion should be considered as valid as the multiple radiocarbon dates on which it is based. Archaeologists will usually reject a radiocarbon date as appropriate for the archaeological manifestation if it does not accord well with the overall regional cultural chronology. This criterion for acceptance of a radiocarbon date is comparable to that employed in geology, palynology, and other sciences utilizing the radiocarbon methodology.

### REVIEW OF ARCHAEOLOGICAL DATA

In this section the archaeological data bearing on the problem of coastal stability will be reviewed for areas of the coast. The coast has been investigated by archaeologists in circumscribed areas that do not correspond directly to the geologically defined sections discussed above. Seven areas that have received more or less attention will be discussed. Of these, only the Boothbay, Damariscotta River, Muscongus Bay, and Pas-

samaquoddy Bay areas were examined with coastal stability and sea-level rise as a major research focus.

### ***The Southwestern Coast***

This section of the coast corresponds to the southwestern geologic compartment of Kelley (1987) and Shipp and others (1985), and extends from the New Hampshire border to Cape Elizabeth at the western end of Casco Bay. Arcuate bays with barrier beach/marsh systems have formed between bedrock capes along here. The metasedimentary bedrock is covered by thick deposits of glacial sediments. Intrusive igneous rock bodies form most of the headland capes.

**Archaeological Research.** Archaeological research in this area has been extremely limited. Only 27 prehistoric archaeological sites are known from 504 km of shoreline, but only about 5% of the shoreline of the area has been surveyed. Recent interest has been sparked by discoveries along the northern Massachusetts and New Hampshire coasts of partially submerged sites in the back-barrier, marsh environment (Robinson, 1985a). Because the coast south of Portsmouth, N.H. is very similar to the southwestern Maine coast, the sites there are pertinent to this discussion. Two partially submerged sites have been test excavated. The Nelson Island site is located in the salt marsh behind Plum Island, Massachusetts. Late Archaic Period artifacts have been discovered at 60 cm below the marsh surface in a paleosol context. An extensive collection from the intertidal mudflat adjacent to the marsh contains many diagnostic Late Archaic Period artifacts (Robinson, 1985a).

At the Seabrook Marsh site a human burial was encountered at an elevation of 2.45 m below the marsh surface. The collagen fraction of the bone dated to  $4185 \pm 255$  B.P. (Robinson, 1985a). Based on Keene's (1971) study of Seabrook Marsh, Robinson estimated that the burial was interred when mean high water (MHW) was 10 ft (3 m) below the elevation of the burial pit. The Seabrook Marsh site also yielded an extensive collection of Late Archaic Period artifacts from primary contexts. Based on archaeological data, the minimum change in the elevation of MHW is about 2.7 m over approximately the past 4000 years.

Robinson (1985b) later carried out a survey of about 10 km of intertidal areas around Scarborough, Maine, in hopes of discovering similar sites. A possible prehistoric hearth was discovered in a buried soil horizon exposed by a ditch through the marsh. No artifacts were discovered with the fire-cracked rock, however, and no date estimates are available.

Another short survey was recently carried out by Will (1986) in the York River area. Only one new prehistoric site was discovered. Collections of prehistoric artifacts in local historical society museums were also examined. Some Archaic age material has been collected in the area, but the provenience of these finds is uncertain. No recent excavations have been carried out in the southwestern section of the Maine coast.

**Discussion.** From the scant evidence available, this section of the coast was occupied at least as early as the Late Archaic

period, roughly 5000 B.P. The research of Robinson (1985a, b) suggests that sites around the marshes can become submerged and preserved by rising, relative sea-level in the low-energy, back-barrier, environment. This process corresponds to delayed erosion in the model of Kraft and others (1983). It is very different from the preservation potential that exists on most of the rest of the Maine coast.

No sites have been reported from the barrier sand beach coast. A few sites have been found at the juncture of sand beach and bedrock promontories. This suggests that sites may have extended out onto the beach, but have long since eroded.

### ***Casco Bay***

The Casco Bay research area extends from Cape Elizabeth to Harpswell Neck. The area falls into the South Central geologic compartment (Kelley, 1987; Shipp and others, 1985). Deformed, gneissic and schistose metamorphic bedrock predominates (Hussey, this volume). These rocks trend NE to SW, and control the orientation and form of the coast. The linear "Calendar Islands" of Casco Bay are formed of these rocks.

**Archaeological Research.** The Casco Bay area has received considerably more archaeological attention than the southwestern coast. Systematic survey began in 1978. Since that time, David Yesner (formerly of the University of Southern Maine) and associates have surveyed 160 km of coastline, mostly in the Calendar Islands. Over 192 sites are known in this research area.

**Discussion.** Late Archaic Period artifacts have been excavated on Great Moshier Island (Doyle and others, 1985). Quahog shell from the base of the shell midden was dated to  $3420 \pm 50$  B.P. (Dic-2428) (Doyle and others, 1985:44). A date of  $4225 \pm 150$  B.P. was obtained on oyster shell from another site on Great Moshier Island (Yesner, 1984a). The Great Diamond Island site (Hamilton, 1985) dates to the end of the Late Archaic Period.

Survey conducted by Yesner (1978) also found four sites where shell midden deposits extend below MHW. The lower strata at a site on Haskell Island extend up to one meter below MHW, and date to  $1200 \pm 120$  B.P. (oyster shell). Occupation levels at another site on Haskell Island were interstratified with salt marsh sediments (Yesner, 1978). A site on Horse Island with shell midden deposits below MHW was dated to  $1520 \pm 110$  B.P. (oyster shell). Assuming that the middens were originally deposited on dry land, relative sea-level rise is indicated.

No other sites from other areas of the coast of Maine are known to extend below MHW. According to the model of Kraft and others (1983), erosion of the sites in Casco Bay must be progressing too slowly to keep pace with relative sea-level rise. Yesner (1978, 1984b), however, has noted extensive erosion of sites in Casco Bay.

Settlement pattern analysis of Casco Bay shows that sites face predominantly either NW or SE (Yesner, 1979, Figure 24) perpendicular to the trend of the bedrock. Sites facing SE would



be exposed to higher wave energies, especially from southeastern storms, than sites facing in other directions. The average wave approach direction for southeastern storms is 158 degrees (Timson and Kale, 1976). Thus, waves may strike the shores of outer islands almost parallel. Waves would be diffracted before reaching less exposed shores. Doyle and others (1985) reported that the Archaic age site on Great Moshier Islands is covered by wave-tossed deposits.

### ***The West-Central Maine Coast***

This research area extends from Reid State Park on the west to Owls Head, Penobscot Bay, on the east. It includes the Boothbay, Muscongus Bay, and St. George River areas. The bedrock of the Boothbay region consists of north-south trending metasedimentary rocks (Hussey, this volume; Osberg and others, 1985). Long, linear islands and peninsulas characterize the form of the coast (Johnson, 1925). From Pemaquid Point to Owls Head the bedrock gradually changes from metasedimentary to granitic intrusive (Guidotti, 1979; Hussey, 1971). To the west, intrusive pegmatites occur in veins. In the central area the bedrock is mixed; large masses of intrusive rocks are common, while to the east granite intrusives predominate.

In the Boothbay area surficial deposits are generally thin, especially on the outer coast (Smith, 1976). Presumpscot Formation marine silts and clays deposited during a Late Pleistocene sea-level transgression (Bloom, 1963; Belknap and others, 1987) appear to thicken towards Penobscot Bay (Kellogg, 1984).

The more linear nature of the Boothbay area coast provides long stretches of fairly protected shores dominated by tidal processes (Kellogg, 1982; Shipp, 1989). In contrast, the Muscongus/St. George area is more exposed and a higher percentage of the shores are impacted by waves (Kellogg, 1984).

**Archaeological Research.** The Damariscotta River attracted early archaeological interest because of the extensive oyster shell middens near the head of tide. This area will be considered in the next section. F.W. Putnam (1883) excavated a shell heap on the southern tip of Fort Island which has since eroded away. Putnam employed a local man, A.J. Phelps, to locate other shell middens. Phelps (1884) collected from many shell middens in Muscongus Bay and measured the dimensions of many.

Several other researchers (e.g., Bates and Bates, n.d.; Moorehead, 1922) explored the area in the early 1900's. Sanger directed a multi-year project of survey and testing in the Boothbay area from 1979 to 1986 (Kellogg, 1982; Sanger, 1982). Eldridge (1980, 1981) surveyed and tested sites in the St. George River area starting in 1980 and continuing to the present (Eldridge, 1980, 1981). Kellogg and Sanger intensively studied the Muscongus/St. George area in 1983 and 1984 specifically to gather information useful for assessing coastal stability, in addition to basic archaeological information (Kellogg, 1984, 1985a, 1985b). In addition, over twenty sites have been test excavated

in the Boothbay area (Carlson, 1986; Chase, 1988). Eight sites were tested in Muscongus Bay, with extensive excavations at the Todd site on Keene Neck (Skinas, 1987). Eldridge has tested at least 10 sites in the St. George region. Overall the west-central area has received some of the most extensive and intensive research of any area of the Maine coast. Over two thirds of the 1350 km of shoreline has been surveyed and 620 sites documented.

**Discussion.** The earliest evidence of occupation in the Maine coastal zone is a Paleoindian type, fluted projectile point collected from a mudflat south of Sawyer Island on the lower Sheepscot River (Crotts, 1985). The significance of this find relative to contemporaneous sea level is ambiguous because of its isolated occurrence, uncertain context, and uncertain age.

A few Middle Archaic Period artifacts have also been recovered from intertidal contexts in the Boothbay area (Crotts, 1985). Evidence of Late Archaic Period occupation is more prevalent in extant sites and has been documented from the Muscongus/St. George area as well (Kellogg, 1985b). Sanger (1975) reported on the amateur excavation of a non-shell site on Monhegan Island with many swordfish remains. Swordfish bone yielded a collagen date of 3750±80 B.P. (SI-1532). Two other Late Archaic Period sites, thought to be of comparable age, are eroding on Monhegan Island.

**Coastal Erosion and Archaeology.** Kellogg's (1982) study of the Boothbay area considered the problem of coastal erosion of archaeological sites, and the Muscongus/St. George project elaborated that research. The purpose of the 1982 study was to determine if the sites known from the Boothbay area were a representative sample of the Ceramic Period occupation (2700 to 350 B.P.), or if biases might be present due to differential preservation. A model for coastal erosion of the area's complex, rocky coast was developed.

Although three general energy zones can be defined, as in Kellogg (1982) and Shipp and others (1985), two modes of erosion occur. Along the exposed, outer coast erosion is controlled by the potentials for storm waves to reach new heights where unconsolidated sediments overlie the resistant bedrock. The outer coast is already eroded. The inner, tide-dominated coast that is not exposed to storm waves, however, is still in the process of actively eroding. Shores along the inner coast commonly expose unconsolidated sediments at or below MHW in bedrock gaps (Figure 2). Thus, any high water event, not only just record breaking ones, can contribute to shore erosion. Furthermore, active scarps are maintained by subaerial processes, such as mass wasting due to spring run off, as well as marine processes. As a result, erosion rates, as indicated by fallen trees and distorted trunk growth, are presently more rapid in areas exposed to lower wave energies.

Settlement pattern analysis (Kellogg, 1982) found that archaeological sites tend to occur along shores that are the most rapidly eroding. A similar situation was found in the Muscongus/St. George area (Kellogg, 1984, 1985a, 1985b); however, erosion was more evident than in the Boothbay area (Figures 3



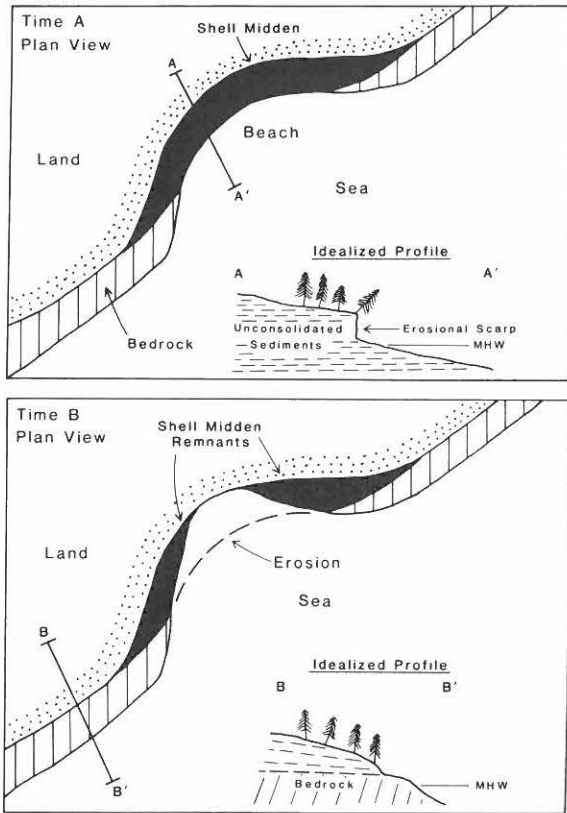


Figure 2. Site erosion model. The plan views show a typical coastal archaeological setting where a beach is present at a bedrock gap. Erosion is somewhat more rapid in the gap, where unconsolidated sediments are exposed to marine processes at lower elevations than over bedrock (see idealized profiles). Over time, shell midden deposits are often eroded into one or more remnants. These remnants are sometimes recorded as separate sites when the gap is large.

and 4). Settlement patterns are similar in the Boothbay and Muscongus/St. George areas, but the bedrock differences across the region produce variations in coastal configuration. Locations selected for occupation were slightly different (Kellogg, 1984). The overall pattern, however, suggests a decidedly marine orientation of coastal settlement. Sites appear to have been selected from the range of possible locations so that relatively easy access to the outer coast would be possible, while maintaining protection from wave-dominated shores. Proximity to fishing (Carlson, 1986) and shellfishing areas also appear to be major factors in site selection (Kellogg, 1982, 1984).

Relative sea-level rise, in most cases, results either in submergence or erosion of archaeological deposits. Only in the case of a site perched high on a promontory might relative sea-level rise have no influence on site preservation. The model of Kraft and others (1983) demonstrates the potentials of site preservation under different conditions of sea-level regime. For most of the coast of Maine, erosion is the much more likely

outcome of relative sea-level rise. No conclusive evidence of submerged archaeological sites has been discovered along the Maine coast, although a few suggestive finds have occurred in Penobscot Bay. Evidence of the erosion of archaeological sites, on the other hand, is obvious and widespread (Kellogg, 1982, 1984; Sanger, 1980; Spiess, 1981).

Very few data are available on erosion rates, although research is in progress (Kelley and others, 1988; Smith and others, 1987, 1988). Studies by Timson (1977) and Nelson (1979) focused on sand beaches. No erosion rates were obtained in the Boothbay study (Kellogg, 1982); however, it was discovered that at least three archaeological sites had completely eroded since their initial discovery 60 to 100 years ago. Some estimates of erosion rates could be obtained for the Muscongus

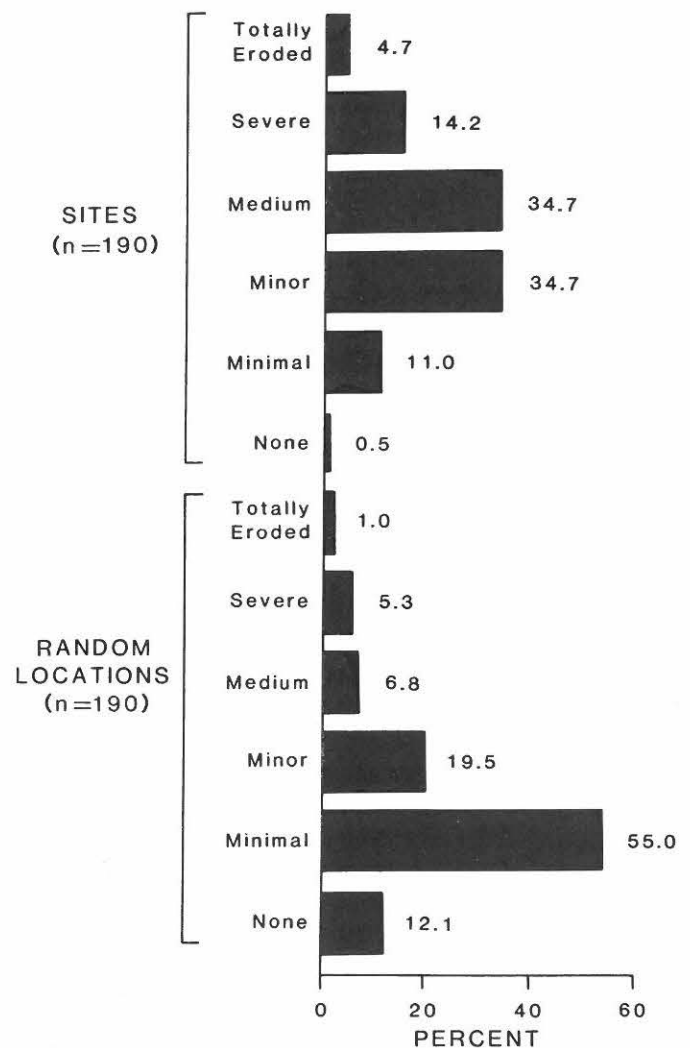


Figure 3. Erosion of Boothbay shores. Erosion assessment was based on the extent and degree of scarp development, and condition of vegetation at the scarp (distorted tree trunks, for example). Field observations were made at each location, based on a classification scheme defined in Kellogg (1982). Data from Kellogg (1982).

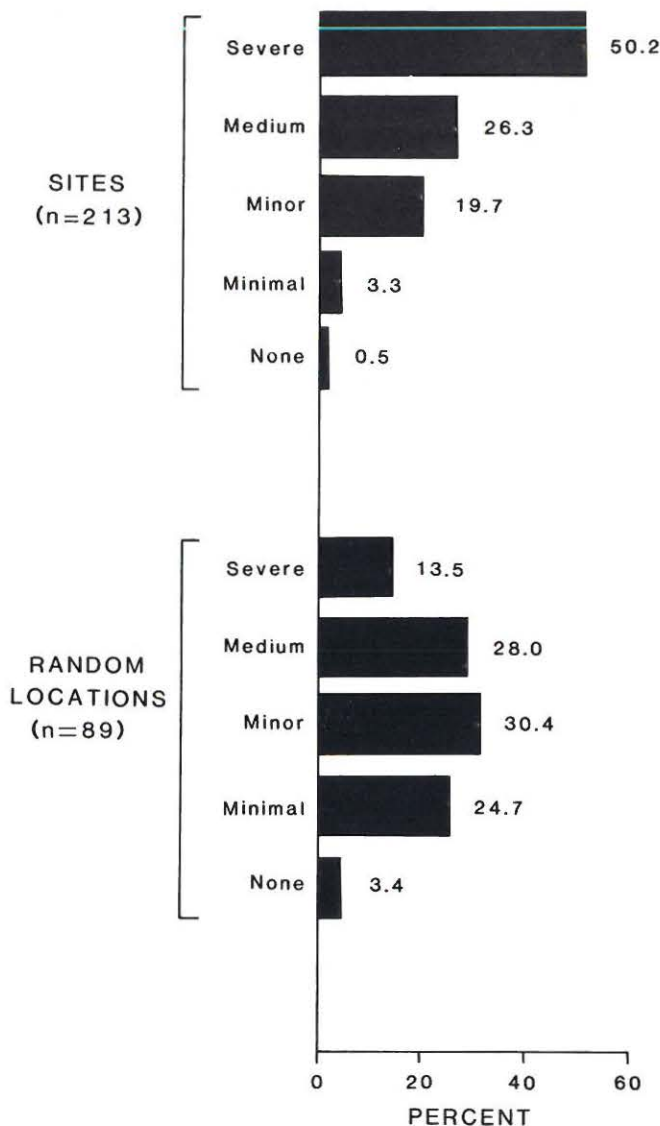


Figure 4. Erosion of Muscongus/St. George shores. Observations based on the classification scheme of Kellogg (1982). Data from Kellogg (1984, 1985a).

Bay area by comparing Phelps' (1884) measurements with modern site extents. Remeasurement of two shell middens visited by Phelps yielded erosion rates of 10 and 5.7 m per 100 years (Kellogg, 1984, 1985a).

Minimum erosion rates were obtained by tree-ring dating living trees that had been undermined by erosion and lowered onto the shore. Ten trees were cored to obtain minimum erosion rates (Kellogg, 1984, 1985a). Minimum erosion rates ranged from 1.7 to 5.1 m per 100 years. Included in the tree ring records obtained by coring is information on growth stresses during the life of the trees. Compression wood, with a different cell structure, forms when trees are tilted during growth (C. Bliss, personal communication). Erosion rates obtained by measuring from the

inception of first compression growth were 2.5 to 12 m per 100 years. The results are in the same order of magnitude as those obtained by remeasuring shell middens.

If these erosion rates are realistic, then evidence of most of the prehistoric occupation on the Maine coast will be gone in the next 100 years. A backwards projection at these rates suggests that a very large number of sites have eroded away completely. Yet, sites are found in such abundance, and evidence of early occupation is so widespread, that a constant erosion rate cannot be the explanation. One explanation may be that erosion rates were slower in the past.

### The Damariscotta River

**Introduction.** Above the towns of Newcastle and Damariscotta on the Damariscotta River there are several large shell middens. The potential for these middens to provide data on local sea-level rise has been recognized for half a century (Goldthwait, 1935). As part of the Nuclear Regulatory Commission project, the middens and the pertinent geological, archaeological, and paleoecological conditions were re-evaluated with the assistance of D. Belknap, Davida Kellogg, T. Kellogg, C. Newell, M. Sanger, and R. Stuckenrath, among others.

Progressive inundation of the Damariscotta River by rising Holocene sea-level was controlled by a series of bedrock sills (Shipp, 1989). The most upstream of these are currently undergoing submergence, and provide an analog for past events in the river. Johnny Orr is the name applied to a bedrock and boulder sill located 1 km upstream from the U.S. Route 1 (Business) bridge linking the towns of Newcastle and Damariscotta (Figure 5). The Indraft is a second, narrower, sill 1.5 km above Johnny Orr. Between the two sills are some of the largest shell middens of the U.S. East Coast, and certainly the largest in New England.

**Archaeological Research.** For over a century, attempts have been made to explain this concentration of middens and their significance for the natural history of the region (Sanger and Sanger, 1986). Goldthwait (1935) recognized that the presence of so many American oysters, *Crassostrea virginica*, represented a marine inundation of the river. He concluded that sea-level had been stable since the time of the origin of the shell middens. Myers (1965), through a combination of geology, shellfish ecology, and some radiocarbon dates on shells, determined that over a meter of sea-level rise must have taken place over the past 2,000 years. The Nuclear Regulatory Commission project has refined, but has not fundamentally altered, Myers' conclusions.

The American oyster is one of a number of species that retreated up Maine rivers in response to cooling waters during the late Holocene. The cooling waters inhibited reproduction so that only relic populations remain today. Oysters are now found only in brackish, warm water situations, where spawning can occur and its major predator, the oyster drill, *Urosalpinx* sp. cannot survive. Oysters are not known from the Damariscotta

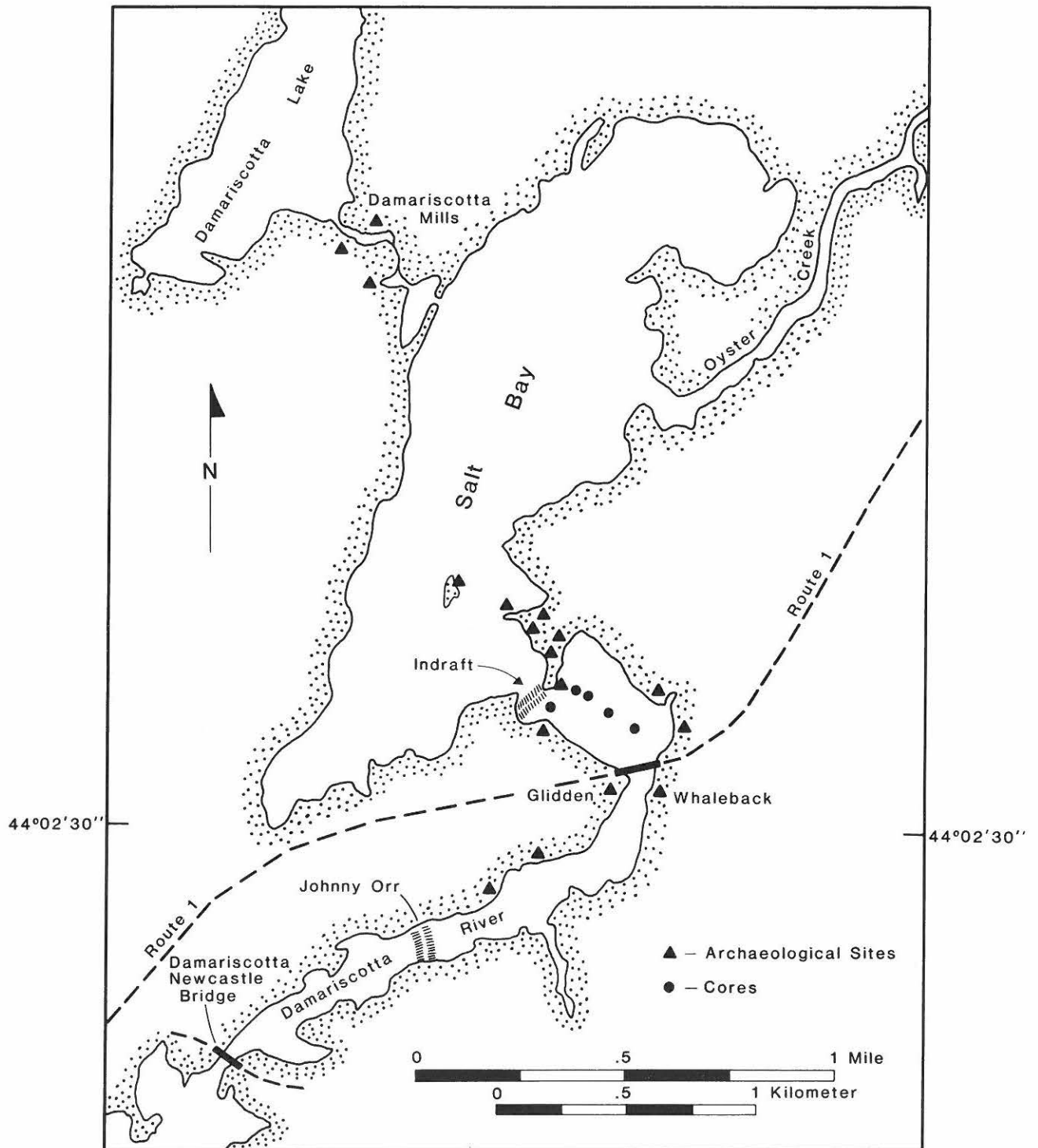


Figure 5. The Upper Damariscotta River area. Bedrock sills, archaeological sites, and coring locations.



River today, although a shellfish biologist (S. Chapman, personal communication) has reported extensive reefs of oysters buried under silt adjacent to the middens. Shipp (1989) identified such features on seismic profiles farther south in the Damariscotta River and verified the presence of oysters by coring. It has been obvious to observers that there must have been a flourishing colony of oysters at some time in the past so that the substantial mounds of shells could have developed. Belknap (personal communication) received a date of  $1325 \pm 40$  BP (SI-7129) on an oyster shell taken from an oyster reef in Great Salt Bay. The introduction of the oysters, and their eventual decline, is closely related to local sea-level rise.

In 1982, several piston cores were taken from an area of deep sediment accumulation in the river between the two sills, Jonny Orr and the Indraft. It was hoped that analysis of the diatoms in the sediments might provide a history of changes in salinity brought about by sea-level rise. Unfortunately, the low incidence of diatoms in the sediment did not permit any conclusions on salinity (Sanger and Kellogg, 1983, Table 2). Apparently the piston cores did not penetrate far enough into the sediments to recover the pre-marine phase. Vibracores, taken in 1984, resulted in a longer sediment record; however, the final results are not yet available. Therefore, the discussion concentrates on the archaeological and paleoecological aspects of the project.

The age of the oyster shell middens is considered a critical aspect of the sea-level rise program because it was not until the sea had risen over the sill at Johnny Orr that oysters could colonize the river above that point. It has always been assumed that the piles of shells represent not only the place of consumption of the oysters, but also the locale of collection. One reason is the huge size of the middens. The Whaleback Midden, located on the east side of the river, was originally up to 4.8 m deep and stretched along the bank for 100 m. A measurement around 1900 found that the Glidden site on the west bank was 9 m deep and extended along the shore for 150 m (Sanger and Sanger, 1986). Less impressive middens also occurred. Included in the middens were abundant indications of occupation, such as fire hearths, human burials, bones of various animal species used for food, and manufactured items. The discovery of extinct oyster reefs in the river adjacent to the archaeological sites, and the evidence for intensive occupation by Native Peoples, argue against any hypothesis that the shells were gathered elsewhere and carried to the river bank for disposal.

The middens were greatly reduced in size by various commercial mining operations for lime, chicken-scratch, and road fill. The largest of these operations, undertaken in 1886, almost completely demolished the Whaleback midden. Fortunately, local antiquarian Abram T. Gamage contracted with the Peabody Museum of Harvard University to watch over the digging, recover artifacts, and make notes and drawings of the excavation. Gamage's notes and artifacts provide the best evidence for the culture-historical reconstruction of the Whaleback (Sanger and Sanger, 1986). Owners of the Glidden

site, opposite the Whaleback, resisted attempts to commercially mine the midden, and with the exception of a Harvard University archaeology expedition in 1935, have adopted a strict conservation stance.

It may be assumed that when the middens started to develop there were enough oysters in the river to make a human settlement worthwhile. Therefore, while the beginning date on the sills does not necessarily provide the age of the first oysters over the sill, it does provide a limiting date. Native Peoples utilized the Damariscotta River since the Late Archaic Period, about 4000 B.P. The exploitation of shellfish on the coast of Maine goes back to at least 5000 B.P. at the Turner Farm site on North Haven Island (Bourque, 1975; Spiess and others, 1983). With the exception of few Archaic Period artifacts incorporated into the Whaleback site, all of the artifacts recovered from the oyster middens represent the Ceramic Period, that is, from about 2500 B.P. onwards. The few Late Archaic Period pieces are considered to be imported as curiosities or incorporated into the midden from an earlier occupation, because Ceramic Period artifacts underlay the Archaic specimens in the same excavation unit. Most of the diagnostic specimens are pottery vessels from the Middle Ceramic Period, dated elsewhere by radiocarbon to between 2200 B.P. and 1200 B.P. There are some cord-wrapped-stick impressed ceramics, all grit-tempered, which are generally from early in the Late Ceramic Period. The absence of any shell-tempered pottery, small triangular projectile points, or Iroquois-like ceramics from the collections indicates the lack of much occupation after 1000 B.P. The archaeological evidence suggests that people began exploiting the resource by 2400 B.P., made extensive use of the oysters, and left by 1000 B.P., or shortly thereafter. It can be argued that this tenure was directly attributable to the effects of sea-level rise in the Damariscotta River.

As part of the Nuclear Regulatory Commission program shellfish biologist Carter Newell (1983) was contracted to prepare a report on the ability of the modern Damariscotta River to sustain an oyster population between Johnny Orr and the Indraft. His analysis, based on a Habitat Suitability Index developed by Cake (1983), indicated that water temperature, salinity, bottom conditions, food supply, and other factors are quite adequate in the river for oysters. The one problem is the presence of predators, especially the oyster drill, which effectively ended recent attempts to culture oysters above Johnny Orr (Newell, 1983).

The American oyster can colonize brackish water with salinities of 10 ppt or less. We speculate that from a parent stock downstream, oyster spat were able to cross the sill at Johnny Orr and establish themselves. At relatively low salinity levels they had no major predators, with the exception of people, and they flourished. As sea-level continued to rise the mean salinity increased until levels reached 20 ppt, the "drill line", after which time the oyster drills and other predators were able to survive and prey on the oysters. (The modern mean salinity is about 25 ppt.) The combination of heavy human predation and the attacks



by the drill resulted in the demise of the oyster population centuries before the arrival of Europeans in the area.

In an attempt to ascertain the date of origin of the middens we obtained samples of oyster shells from the Glidden Midden. Seven radiocarbon dates from these shells ranged from  $1720 \pm 50$  B.P. to  $2330 \pm 50$  B.P. (SI-6356 to SI-6362). These dates confirm earlier assays reported by Broecker and others (1956) and Bradley (n.d.), as reviewed by Sanger (1985a). The lowest shells, but not the oldest date, were obtained from 70 cm below MHW in a small excavation pit. At present there is no way of determining from the evidence whether or not these shells represented the first shells to be deposited at that part of the midden, or whether they were shells that had fallen off the face of the midden from a higher level. If the shells were in their primary place of deposition, it would suggest either that they were thrown into the water, or that the midden commenced when mean high tide in the river was -70 cm. Historic accounts, confirmed by examination of 19th century photographs, indicate that the front of the Glidden site has been eroded by the Damariscotta River. The narrow platform in front of the site is an erosional remnant, and it was into this platform that the pit was dug to obtain the deepest shells. It seems likely, therefore, that the shells, if in primary context, came from the inside of the midden, which was mostly likely on dry ground at the time of initial building. A proper excavation, complete with full stratigraphic controls, will be necessary to confirm or reject this hypothesis. Our suspicion is that the Glidden midden began forming when the tidal range above Johnny Orr was less than half of what it is today.

**Discussion.** The artifacts recovered from the Glidden site and the Whaleback indicate a period of intense occupation between about 2200 B.P. and 1500 B.P., with perhaps only occasional use for another few centuries. Shells probably began to accumulate no earlier than 2400 B.P., a conclusion based on the radiocarbon dates and the comparative dating chronology. Because the aboriginal peoples were utilizing other riverine resources from at least 4000 B.P., and clearly knew how to gather shellfish, the most likely conclusion is that the oysters were not available in sufficient quantities to make collection profitable until about 2400 B.P. By this date sea-level must have overtopped the sill at Johnny Orr, and in the process have created a brackish environment.

The tidal range above Johnny Orr is approximately 1.1 m, whereas it is three times that 1 km downstream at Newcastle. Therefore, at a minimum, sea-level must have risen at least 1.1 m in the 2400 years represented by the shell middens. The rate of rise would be somewhat slower if the effective breaching of the sill occurred substantially earlier than 2400 B.P. As research progresses on the analysis of the sediment cores we hope to have available a plot of salinity-sensitive diatoms in dated sediment cores. Another approach to refinement of the sea-level rise in the river would be an analysis of oyster shells taken from properly excavated and carefully dated contexts in the Glidden site. To date, the owner of the site has not been receptive to any further investigation.

### **Penobscot Bay to Frenchman Bay**

Penobscot Bay extends from Owl's Head to Schoodic Point and includes part of the central Maine coast with granite bedrock and other volcanics. Thus, resistant rock underlies many archaeological sites. The oldest known sites on the Maine coast are found in this area. Unfortunately, no systematic site erosion observations, such as described for Boothbay and Muscongus Bay, have been reported.

**Archaeological Research.** Penobscot Bay forms the estuary of Maine's largest river. Within it are a great many, islands and coves well suited to the marine adapted Native Peoples. Some of the early coastal research took place here (Byers, 1979; Hadlock, 1939; Moorehead, 1922; Rowe, 1940). The region assumed definition with the advent of Bourque's (1971, 1975, 1976; Bourque and Cox, 1981) survey and excavation.

At the important Turner Farm site on North Haven Island, Bourque has described a series of occupations extending back to the beginning of the Late Archaic. A date of  $5290 \pm 95$  B.P. (SI-1925) from Occupation 1 is the oldest radiocarbon date received from a Maine coastal site. Stratified above the earliest component is Occupation 2, a Moorehead phase assemblage, dated to between 4500 and 3700 B.P. On the beach in front of the site a Middle Archaic Period, Stark-like projectile point was found (B. Bourque, personal communication), which suggests occupation at the same site for 6,000 years or more. Other Middle Archaic Period points have been reported from eroded sites, while an Early Archaic Period, Kirk-like point has been reported from Surry (Sanger, 1975). At the Goddard site on Naskeag Point, a date of  $4995 \pm 100$  B.P. (SI-4255) was obtained on intact deposits (Bourque and Cox, 1981). At the Nevin site, in Blue Hill Bay, a Late Archaic Period occupation was excavated by Byers and Johnson (Byers, 1979). The site produced a number of radiocarbon dates, including:  $4245 \pm 115$  B.P. (SI-1551-A2) and  $4195 \pm 60$  B.P. (SI-1551-C) (Byers, 1979). Other sites in the area with similar occupation include the Waterside site in Sorrento (Rowe, 1940) and Taft's Point in West Gouldsboro (Hadlock, 1939). At Duck Harbor, on Isle au Haut, salvage excavations in conjunction with badly eroding non-shell midden sites yielded Late Archaic Period artifacts (Sanger, 1981b). Unfortunately, there are no radiocarbon dates available from Duck Harbor.

The cultural manifestation following the Moorehead phase in Penobscot Bay was the Susquehanna Tradition, which began in the area about 3800 B.P. Intact deposits of this tradition are present at the Turner Farm site and at a number of locales in the Penobscot Bay region.

Finally, fisherman dragging the bottom have, from time to time, brought up artifacts (Sanger, 1988; Spiess and others, 1983). Off Lazygut Islands, near Deer Isle, an oyster shell, in a general association with artifacts, was dated at  $6100 \pm 65$  B.P. (SI-4650) (Spiess and others, 1983). The finds were in about 8 m of water. It is not known if the oyster was from a midden deposit or a natural context. It is hoped that additional research

in the area will be carried out, because it could provide a potentially very useful date for land submergence in the area.

**Discussion.** There are more sites older than 4000 B.P. in this part of the Maine coast than any other. The millennium 4000 to 3000 B.P. is also well represented. When compared with the Boothbay region, for example, where equally intensive research has been conducted, the differences in the ages of preserved sites are quite striking. Compared with the Passamaquoddy Bay region the contrast is even greater. To some extent this is probably due to the resistant granitic and volcanic bedrock that dominates the area; on the other hand, it may also be explained by a greater degree of stability in the central Maine coast.

### *Englishman and Machias Bays*

The bedrock of this section of the coast is predominately metavolcanic. The easternmost of the coastal granitic batholiths outcrop to form Great Wass and Head Harbor Islands at the western boundary of the area. Unconsolidated glacial deposits are extensive. On the south shore of Roque Island a classic, log-spiral sand beach has formed (Nelson and Fink, 1980; Fink and others, 1988).

**Archaeological Research.** Only sporadic research took place in this region before 1978. Robert MacKay (University of Maine) excavated a site in Machias Bay in 1973. Sanger (1979) conducted a preliminary survey and tested several sites in 1978. Excavations were carried out on a site on Great Spruce Island in 1982 (Sanger and Chase, 1983). Sanger returned to the Roque Islands in 1985 for more excavation and survey (Sanger and Kellogg, 1985b).

**Discussion.** Late Archaic Period artifacts were found at sites excavated by MacKay in Machias Bay, and in Site 61-34 on Roque Island (Sanger and Chase, 1983). None are associated with radiocarbon dates, however.

Many fewer sites are found along the coast in this area in comparison to other areas of the coast (Sanger and Kellogg, 1985b). This may be due to erosion. The mainland shores of Englishmans Bay are mostly "linear fringing beaches" (Shipp and others, 1985:22) with steep, unvegetated scarps of unconsolidated sediments. In addition, some of the metavolcanic bedrock is highly fractured, so that it is subject to erosion by waves and frost action. The erosion of unconsolidated sediments can be influenced by the erosion of the bedrock. In the Boothbay and Muscongus Bay areas, bedrock erosion is much less prevalent.

Seven trees were cored during survey of the Roque Island area to obtain minimum erosion rate estimates (Kellogg, unpublished data). Erosion rates ranged from 1.71 to 7.92 m per 100 years. It is impossible to satisfactorily compare the limited samples for this area with those from the Muscongus Bay area, except to note that all but one erosion rate overlapped. Erosion might be taking place more rapidly in the Roque Island area.

Although the sparseness of archaeological sites might be due to more rapid erosion, there are indications that this area may not have been as extensively settled as other areas of the coast (Sanger and Kellogg, 1985b).

### *Passamaquoddy Bay*

**Introduction.** Passamaquoddy Bay, located on the Maine-New Brunswick border, is a large embayment that is rich in archaeological sites. Concern for erosion of sites in this region has led to considerable thinking about the interrelationship between archaeology and sea level (Ganong, 1899; Matthew, 1884; Sanger, 1971, 1985b, 1985c). Archaeological, geological, and biological research in the Passamaquoddy Bay region began over a century ago. In the intervening years a substantial body of data has been developed and reviewed (Moyse, 1978; Sanger, 1986; Thomas, 1983). It has also been a focal point for research in connection with the Nuclear Regulatory Commission project because of an apparently anomalous rapid rate of crustal subsidence.

**Archaeological Research.** The northern side of Passamaquoddy Bay is the most intensively researched archaeological area in the Maine-New Brunswick portion of the Gulf of Maine. Despite this work, no sites have been found that demonstrate habitation older than 3,000 years. Whereas in the central Maine coast the Late Archaic Susquehanna Tradition (3800 B.P. to 3200 B.P.) is well represented, it is thus far absent from Passamaquoddy Bay. The fact that Susquehanna Tradition artifacts occur in the St. Croix River watershed, the major river draining into the Bay (Kopeck, 1985), as well as in Saint John, New Brunswick, harbor sites (Sanger, 1971), suggests that people of this tradition also dwelt in the Passamaquoddy Bay area. The earliest coastal occupations are represented by nearly a dozen sites where large, stemmed bifaces occur with large scrapers in non-shell contexts. Many of these assemblages underlie later shell middens, although some are isolated (Sanger, 1986). Some of the bifaces suggest a Susquehanna Tradition ancestry. Two radiocarbon determinations of around 2400 B.P. are the earliest of numerous Passamaquoddy Bay site dates. On typological grounds it is possible that some of the early, non-shell components are as old as 3000 B.P. Compared with the clear evidence for sites at least 1000 to 2000 years older in the central Maine coast region, erosion of the older sites would seem to be the best explanation.

Around 2000 B.P. there is ample evidence for coastal occupation around Passamaquoddy Bay. These sites reflect a dual marine-terrestrial exploitation pattern which varies little over the 1500 years from 2000 B.P. to the Contact Period about 350 B.P. (Sanger, 1985c, 1986). The sites are shell middens, dominated by *Mya arenaria* with excellent preservation of organic remains. Sites are located on the modern shoreline, and conform to the familiar pattern of site locations chosen to maximize utilization of marine resources and availability (Kellogg,

1982). To date, three very small sites in the area (about 3% of the sample), are not located right on the shoreline; but they are very close to the shore.

The presence of apparent non-shell sites around 3000 B.P. led to a coring project in 1977 to determine whether or not shellfish were present in the area. A series of piston cores was taken in Digdeguash Harbour, a drowned river valley, near where a number of sites occurred. One core intercepted a *Mya arenaria* shell which dated to  $5375 \pm 75$  B.P. (SI-3927) (Sanger, 1985b). Another date, taken on organics in the sediment from just below the shell, confirmed the shell date. The results brought into question the 9 mm/yr rate of relative sea-level rise in eastern Maine predicted from Tyler and Ladd's (1980) geodetic leveling data, and encouraged another coring operation sponsored by the Nuclear Regulatory Commission project. As presented in Sanger (1985b), there are many uncertainties associated with the Digdeguash Harbour core dates and they should not be used to generate a relative sea-level rise curve for Passamaquoddy Bay. However, they do indicate that a simple projection backwards in time of the recent rate of sea-level rise is problematic.

The bedrock geology of Passamaquoddy Bay has been reviewed by Gates (this volume). Among the many lithic units is the Upper Devonian Perry Formation which outcrops in various places. This formation varies in composition, which affects its ability to resist wave erosion. Where there are cobble-sized clasts the eroded face is near vertical; however, those outcrops lacking the clasts tend to erode rapidly. Sites located on Perry Formation are rare, probably due to the tendency to erode. In the Bay there are also Silurian-Lower Devonian volcanics, and it is on these more resistant outcrops that most of the archaeological sites are located.

At desirable places there is evidence that the Native Peoples lived off and on at the same site for close to 2000 years. Throughout this period we can reconstruct, from the abundant faunal remains in the sites, a livelihood that was very dependent on the marine environment. It suggests that during this later phase of prehistory there was little inland migration of beaches, and thus relative stability of sea-level. As described elsewhere (Sanger, 1985b, c), if there was sea-level rise comparable with that reconstructed from the releveling studies (Tyler and Ladd, 1980; this volume), then at 2000 B.P., boat-using, marine-oriented peoples were selecting campsites well back (up to 1 km) in the woods, and continued to live there, while the sea was gradually getting closer and closer.

Previously, Sanger (1985b:52) concluded:

"1. The modern sea-level rise of up to 9 mm per year in eastern Maine is a recent phenomenon that is probably no more than a few hundred years old;

2. Prior to the recent acceleration in sea-level rise there was a period of relative stability from at least 2000 years ago and possibly since 3000 years ago;

3. Before 2500 to 3000 years ago the sea-level rise might have been greater once again."

We see no reason to alter these observations based on the archaeological record.

**Discussion.** Sea-level rise in Passamaquoddy Bay is reflected in the erosion rates of archaeological sites. The evidence points to rapid, on-going erosion, at a pace that could not have much antiquity or else there would be no surviving archaeological record, unless the Native Peoples lived well back in the woods, and away from the active shoreline. For marine-adapted people, using canoes, this scenario make no sense. The conclusion is that after a period of rapid mid-Holocene sea-level rise, there was a slow-down, followed by an acceleration beginning some time after 1000 B.P. We feel this reconstruction is basically in agreement with the combined results of other lines of investigation of sea-level rise.

## CONCLUSIONS

When one of us (Sanger) first began archaeological research on the Maine-New Brunswick shoreline in the late 1960's, differential erosion of archaeological sites was noted. In recognition of the importance of sea-level rise in an attempt at explanation of prehistoric cultural adaptation, Sanger asked H.W. Borns, Jr. to collaborate on a study of sea-level rise in eastern Maine. A National Science Foundation grant to the University of Maine helped to finance the research that led to the original Addison Marsh coring project (Thompson, 1973). Since then, various attempts have been made to integrate sea-level rise into the regional archaeology, as reviewed earlier in this paper. The initial impression of greater site erosion in eastern coastal Maine remains. We discuss possible reasons with reference to some of the assumptions discussed at the outset. To review briefly, the oldest existing sites on the Maine coast occur in the central coastal region, specifically Penobscot Bay and east to Frenchman Bay. Several sites in the 4000 to 5000 year old range are found there. Westward, there are fewer mid-Holocene age sites, while in eastern Maine and Passamaquoddy Bay there are no dated sites older than 2400 B.P. and none by comparative dating thought to exceed 3000 years in age. Turnbull (1988) extended these observations into the upper Bay of Fundy.

We feel that this distribution is real, as opposed to an artifact of sampling. While there still remain many areas of the coast that have not been surveyed in detail, the last decade has witnessed considerable effort between Casco Bay and Machias Bay. Canadian scholars have continued their survey efforts in the Passamaquoddy Bay region (Black, 1984; Davis, 1982).

What, then, is the possibility that the site-age relationship is a reflection of a differential settlement pattern that resulted in earlier occupation of the central Maine coast? The distribution of Susquehanna Tradition sites in the study area is instructive. Susquehanna Tradition sites occur in the littoral, as well as inland locations throughout Maine, and as far east in the Bay of Fundy as Saint John Harbour. Although there is a wide range of dates, sites of this tradition usually range from about 3800 B.P. to 3200 B.P. In the central Maine coast the distinctive artifacts of this



period occur as Occupation 3 (third from the bottom, or earliest) at the Turner Farm site (Bourque, 1976), and occur as the second occupation at other sites, such as Nevin in Blue Hill Bay (Bourque, 1971). Clearly, Susquehanna components are not the earliest occurring in Penobscot Bay or in the Frenchman Bay area. In Passamaquoddy Bay, and also in the Englishman-Machias Bay area, there are no known Susquehanna components in any of the existing sites. However, the distinctive Susquehanna bifaces and drills are plentiful in collections from the St. Croix River system (Kopeck, 1985; Sanger, 1986). This pattern suggests that Susquehanna sites probably existed in Passamaquoddy Bay and have since been eroded.

The geological controls are uneven along the coast. Most susceptible to erosion are the unconsolidated sediments that cap bedrock, as for example, the bluffs near Machias and in Casco Bay (Hay, 1988). Bedrock in the study area is not uniformly resistant to erosion. The weakly-cemented Perry Formation in Passamaquoddy Bay erodes very rapidly, resulting in substantial loss of shoreline in recent decades. In Passamaquoddy Bay, as discussed earlier, there are two very different bedrock formations underlying sites. Nearly all of the sites rest on the Silurian volcanics which are much tougher than the Perry sandstones. The former rocks appear to be much closer to the granites of the central Maine coast in terms of their ability to resist erosion. Even the non-granitic volcanic bedrock is liable to shattering and wasting under the battering of the sea and the effects of frost action. In the absence of a locally derived bedrock "erodability" scale, we can only note that the granites of the central Maine coast tend to be the most resistant of the bedrock we have observed underlying archaeological sites. Surely, this has contributed to the preservation of older sites in the Penobscot Bay to Frenchman Bay area. However, not all of the older sites are on granite, so this cannot be the only factor. In addition to the bedrock beneath a site, preservation depends on the effective wind fetch which, together with other factors, translates into wave energy striking the shore. In conclusion, while the surface geology and geography of each site is critical, these alone cannot explain the pattern of site distribution. Eventually, every site locality must be studied individually.

In the introduction we commented that archaeology has been used to assist in the derivation of relative sea-level curves in many parts of the world. We feel, however, that many of the assumptions, or conditions, that we discussed were not adequately considered in some previous studies. Cognizant of the problems involved with proxy dating of older land surfaces, we offer two types of observations on relative sea-level rise - absolute and relative.

The only absolute data our research has produced to date pertain to the Damariscotta River, where no less than 1.1 m of sea-level rise has occurred over the sill at Johnny Orr over the past 2400 years. In this study, it is not the age of the archaeological surface, but rather the age of the oysters that make up the site matrix. Nevertheless, this could be a significant figure for two reasons; first, the data help to fill the gap left after coring by

Belknap and others (Shipp, 1989) downstream; and second, they highlight the potential of such geoarchaeological situations for future research. Some of the western Maine coastal sites where archaeological deposits are currently below MHW approach an absolute figure; however, there are too many assumptions that must be made to have any confidence in the results to date.

The relative data are suggestive and tend to support other lines of inquiry. Assuming that site preservation is related to relative sea-level rise, the least amount of rise over the past 5000 years would appear to be in the central Maine coastal region, specifically the Penobscot to Frenchman Bay area. The greatest amount of sea-level rise over the same time period seems to have occurred in Passamaquoddy Bay. Intermediate between these extremes is the coast west of Penobscot Bay. For Passamaquoddy Bay, our data suggest rapid rise up to about 3000 years ago, followed by a reduced rate, and then an acceleration in the past millennium. To the extent that rapid erosion leading to site loss is a factor of localized relative sea-level rise, the situation in eastern Maine and Passamaquoddy Bay indicates high modern rates of rise.

From our specific case studies and overall assessments we suggest several follow-up projects that could provide more of the absolute types of data. Interdisciplinary studies should be carried out at a number of sills where reversing tidal falls occur. Whereas at Johnny Orr on the Damariscotta River the breaching of the sill probably occurred by at least 2500 years ago, there are many other sills along the coast where the depth of water over the sill is substantially less, and the date of incursion possibly younger. Kellogg (1984) has reported two localities in the Muscongus Bay area where the marine incursion probably occurred more recently than it has at Johnny Orr. The Salt Pond in Blue Hill Bay (Snow, 1972) is another example of where useful research could be conducted leading to absolute data on sea-level rise.

Another area of inquiry might be a renewed examination of the Monhegan Island situation. In the large Meadow on the south end of the Island, Bostwick (1978) obtained rather surprising data on absolute sea-level rise that do not conform with standard relative sea-level rise curves projected for the central portion of the Gulf of Maine. The fact that Late Archaic Period sites in the 4000 year range still exist on the Island is an anomalous situation with respect to the mainland of the Boothbay and Muscongus Bay region, where such sites have not yet been reported despite the much larger sample of sites.

The Penobscot Bay to Frenchman Bay area, featuring the oldest known sites on the coast, could be examined with a methodology derived from our experience in the Boothbay-Muscongus Bay area. In other words, detailed erosion studies and examination of the factors surrounding the preservation of the oldest sites to assess, if possible, the complex of factors that have led to the greater degree of site preservation. Sea-level rise could be assessed as one factor influencing site preservation.

Despite the attention paid to the Addison area in terms of salt marsh studies and historical structure research, little is



known of the prehistoric archaeology. Similarly, in those regions where the archaeology is best studied, the other disciplines have not been emphasized. Coordination of effort to a higher degree might prove profitable, and could lead to greater convergence of data sets.

Finally, we note in conclusion that the map published by Tyler and Ladd (1980; this volume) as a result of the releveling studies is a predictor for what we found in the archaeological data base. We would conclude that there is in fact differential subsidence ongoing along the coast of Maine. It is entirely possible, from our perspective, that this is a relatively recent phenomenon, dating from the last 1,000 or less years.

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